

CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-186
WESTERN NORTH FRONTAL FAULT ZONE AND RELATED FAULTS,
SAN BERNARDINO COUNTY

by

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INTRODUCTION

Potentially active faults in southwestern San Bernardino County that are evaluated in this Fault Evaluation Report (FER) include strands of the North Frontal Fault zone (NFFZ) (White Mountain Thrust System, Sky High Ranch, Ocotillo Ridge "fold", and Ord Mountains fault zone), Arrastre Canyon graben (Bowen Ranch, Arrastre Canyon Narrows, and Lovelace Canyon faults), Tunnel Ridge lineament, and related faults (figure 1). The northwestern San Bernardino Mountains study area is located in parts of the Fifteenmile Valley, Apple Valley South, and Lake Arrowhead 7 1/2-minute quadrangles (figure 1). The eastern NFFZ, located adjacent to the northwestern San Bernardino Mountains study area, is evaluated in FER-182 (Bryant, 1986). These faults are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (Hart, 1985).

SUMMARY OF AVAILABLE DATA

The northwestern San Bernardino Mountains study area is transitional between the Mojave Desert and Transverse Ranges geomorphic provinces. The Mojave Desert geomorphic province, located in the northern and western parts of the study area, is characterized by generally northwest-trending, right-lateral strike-slip faults. In contrast, the Transverse Ranges geomorphic province, located in the southern part of the study area, is generally characterized by east-trending structures. Both the northwest-trending and west-trending faults are the result of compressional tectonics along the San Andreas fault system. The interaction between these two tectonically active provinces has resulted in a structurally complex area.

Topography in the study area ranges from gently sloping alluvial fans to relatively steep, north- and west-facing slopes. Development in the study area is generally low to moderate in the eastern part of the study area, but is moderate to relatively high in the vicinity of Apple Valley. Rock types in the study area include pre-Mesozoic roof pendants comprised of gneiss, marble, and quartzite, Mesozoic plutonic rocks, and Quaternary alluvium (Dibblee, 1974; Miller, 1975-77; Meisling, 1984). Quaternary alluvial deposits consist of mid- to late-Pleistocene Ord River Gravels (Meisling, 1984), late Pleistocene and Holocene alluvial fans, and late Pleistocene and Holocene Mojave River terrace deposits.

NORTH FRONTAL FAULT ZONE

The North Frontal fault zone (NFFZ) is a major range front fault zone along which uplift of the northern San Bernardino Mountains has occurred. The NFFZ in the study area consists of a complex zone of generally east-, north-, and northwest-trending reverse and strike-slip faults. Included in the NFFZ in the study area are the White Mountain Thrust System, Sky High Ranch fault, Ocotillo Ridge "fold", Ord Mountain fault zone, and related faults (figure 1).

Cumulative displacement along the NFFZ is not well-documented. The onset of deformation and uplift in the northern San Bernardino Mountains is thought to have commenced during mid- to late-Pliocene time and has continued through late Pleistocene time (Dibblee, 1975; Sadler, 1981, 1982; Meisling, 1984). Meisling (1984) reported that vertical displacements of Pleistocene alluvial fans (his Qf2 unit) probably do not exceed 70 meters along the west front of the Ord Mountains. Although absolute ages of the alluvial fans are not precisely known, preliminary age estimates presented in FER-182 (Bryant, 1986) suggest that alluvial fans equivalent to Meisling's Qf2 unit are approximately 130,000 years old, based on soil-profile development, degree of surficial weathering of boulders, and degree of preservation of constructional surface morphology. Clark and others (1984) reported a late Quaternary slip-rate of 0.07 to 0.14 mm/yr along the Ord Mountain fault zone (figure 1). Meisling (1984) estimated that faults along the west flank of the Ord Mountains have a vertical slip-rate of less than 1 mm/yr.

Mendenhall (1905) first recognized that the San Bernardino Mountains are an extremely youthful mountain range, based on the extensive upland erosion surface and the steep north-facing escarpment. Vaughn (1922), Woodford and Harriess (1928), Gillou (1953), Richmond (1960), and Hollenbaugh (1968) all reported evidence of late Cenozoic deformation and faulting along the north front of the San Bernardino Mountains. These maps are not evaluated in this FER because either the scale of the maps is too small, or the mapping (especially of late Quaternary faulting) is too generalized. Mapping that is evaluated in this FER includes Dibblee (1974), Miller (1975-77), and Meisling (1984). None of these maps are annotated with geomorphic evidence of recent faulting.

White Mountain Thrust System

The White Mountain Thrust System is a complex, generally east-trending, south-dipping thrust fault mapped in various configurations by Dibblee (1974), Miller (1975-77), and Meisling (1984) (figure 2a). All three workers mapped late Pleistocene alluvium as offset along strands of the White Mountain Thrust System, but Holocene alluvium is not offset (localities 1, 2, figure 2a).

Meisling (1984) reported that the fault zone was active principally during an older range front thrusting event and that, in general, the fault zone has probably been inactive since the beginning of the Pleistocene. Locally, however, strands of the White Mountain Thrust System offset late Pleistocene alluvial fans (locality 1, figure 2a). Meisling postulated that these recently active strands have been reactivated in association with the Sky High Ranch fault (figure 2a). These recently active strands exclusively occur on the northeast, or downslope side of the Sky High Ranch fault, suggesting that gravitational sliding may be a contributing factor in reactivation. The total magnitude of late Pleistocene displacement is not known, but is assumed to be small by Meisling.

Sky High Ranch Fault

The Sky High Ranch fault is a northwest-trending, vertical to near-vertical, right-lateral strike-slip fault (Meisling, 1984) (figure 2a). The fault has also been mapped by Dibblee (1974) and Miller (1975-77). All three workers mapped late Pleistocene alluvium as offset along the Sky High Ranch fault (e.g., locality 3, figure 2a). The location of the fault as mapped by the three workers agrees fairly well along the central segment of the fault, but significant differences occur along segments to the southeast and northwest (figure 2a). Northwest of locality 3, the Sky High Ranch fault splays into two branches: the southern branch joins with the Arrastre Canyon Narrows fault and the northern branch continues along a northwest projection (figure 2a). Dibblee (1974) and Miller (1975-77) mapped this feature as a south-dipping, reverse fault that offsets late Pleistocene, and possibly, Holocene alluvium (figure 2a). Meisling (1984) mapped a fold in late Pleistocene alluvium west of sec. 15, T4N, R2W and stated that surface rupture of the late Pleistocene alluvial fan deposits could not be demonstrated.

Meisling reported that the Sky High Ranch fault has abundant geomorphic evidence of recent right-lateral strike-slip faulting, such as offset drainages, ponded alluvium, scarps, and shutter ridges. Right-lateral strike-slip displacement of up to 1/2 km has occurred along the Sky High Ranch fault since deposition of late Pleistocene alluvial fans (Meisling's Qf2 unit) (Meisling, 1984, p. 206). Meisling assigned a late Quaternary slip-rate of 1.25 mm/yr for the Sky High Ranch fault.

Ocotillo Ridge "Fold"

The Ocotillo Ridge "fold" is a generally east-trending feature that has been mapped as an anticline by Dibblee (1974), a faulted anticline by Miller (1975-77), and a monoclinial warp by Meisling (1984) (figure 2a). Mid- to late-Pleistocene Ord River Gravel is deformed and Meisling reported that late Pleistocene alluvium is deformed. To the southwest, the Ocotillo Ridge "fold" joins with the Ord Mountain fault zone and to the east the Ocotillo Ridge "fold" probably joins with the Sky High Ranch fault (Meisling, 1984) (figure 2a). Miller mapped the Ocotillo Ridge structure as a thrust fault that offsets late Pleistocene and, possibly, Holocene alluvium (figure 2a).

The Ocotillo Ridge "fold" is delineated by a north-facing scarp in mid-Pleistocene alluvium. Meisling trenched across this scarp and did not find evidence of faulting (locality 4, figures 2a, 4). The approximately 20-meter-long trench exposed a 55° north-dipping section of coarse fluvial sand and gravel overlying massive debris-flow deposits. Carbonate-filled fractures were reported in the debris-flow deposits, but no units were reported to be offset. Liquefaction features were observed in a coarse sand bed and Meisling interpreted these features as seismically related. Meisling concluded that the Ocotillo Ridge "fold" is a monoclinial warp developed over a fault in basement rocks. This buried fault is probably a continuation or extension of the Ord Mountains fault zone (Apple Valley Highlands or Juniper Ranch faults). Meisling interpreted the scarp-like features delineating the north side of Ocotillo Ridge to be a resistant gravel bed within Ord River Gravel deposits.

Ord Mountains Fault Zone

The Ord Mountains fault zone is a generally north- to northeast-trending zone of both low-angle reverse faults (Apple Valley Highlands and Deep Creek faults) and high-angle faults (Juniper Ranch and Powerline Road faults).

Apple Valley Highlands Fault

The Apple Valley Highlands fault (AVHF) is a generally north-trending, somewhat arcuate, east-dipping reverse fault (figures 2a, 2b). The AVHF was mapped by Dibblee (1974), Miller (1975-77), and Meisling (1984, figures 2a-2b). Late Pleistocene alluvial fans are mapped as offset by all three workers and Holocene alluvium is juxtaposed against late Pleistocene alluvium at localities 5 and 6 (figure 2a) (Miller, 1975-77; Meisling, 1984).

The maximum down-to-the-west vertical displacement of late Pleistocene alluvium is about 70 meters (Meisling, 1984). Meisling reported that the AVHF is delineated by a well-defined, west-facing scarp in late Pleistocene alluvium (his Qf2 unit). However, Meisling stated that the Qf2 alluvium has a stage IV K horizon and oxidized B soil horizon, indicating that the alluvium is probably greater than 100,000 years old. Meisling estimated the age of the Qf2 unit to be greater than 100,000 ybp and less than 730,000 ybp, preferring an age of about 400,000 ybp. Meisling stated that, although the west-facing scarp in Qf2 deposits is well-defined, the well-indurated nature of the alluvium, the rounded crest, and the incised drainages argue against very recent (Holocene) displacement. However, Meisling reported that the laminated K horizon and B soil horizon are warped downward at the scarp, indicating that faulting is much more recent than the age of the Qf2 deposits (Meisling, 1984, p. 187). Holocene alluvial fans that cross the AVHF are not offset. Meisling points out the age of these small fans is not known and could conceivably be late Holocene in age. Meisling assigned a preferred late-Quaternary slip-rate of 0.14 mm/yr for the AVHF.

Deep Creek Fault

The Deep Creek fault is a northeast-trending, east-dipping reverse fault mapped by Miller (1975-77) and Meisling (1984) (figure 2b). Dibblee (1974) mapped a generally northeast-trending fault that partly coincides with the Deep Creek fault mapped by Miller (1975-1977) and Meisling (1984) and with the Powerline Road fault mapped by Meisling (1984) (figure 2b). The Deep Creek fault is interpreted by Meisling to connect with the AVHF along an east-northeast-trending tear fault.

The Deep Creek fault offsets late Pleistocene alluvium a maximum of 30 meters, down to the west (Meisling, 1984). The fault is concealed by Holocene alluvium and, locally, Miller (1975-77) mapped the fault as concealed by late Pleistocene alluvium (locality 7, figure 2b). A segment of the Deep Creek fault is exposed in the east abutment of the Mojave River Dam (locality 8, figure 2b). Cretaceous granitic bedrock is thrust over mid-Pleistocene alluvium; the fault dips 45° southeast (figure 2b).

Meisling (1984) considered the Deep Creek fault to be potentially active. He estimated a preferred late Quaternary slip-rate of 0.14 mm/yr for the Deep Creek fault.

Juniper Ranch and Powerline Road Faults

The Juniper Ranch and Powerline Road faults are northeast to north-northeast-trending, high-angle faults associated with the Ord Mountains fault zone (figures 2a, 2b). Meisling (1984) mapped both the Juniper Ranch and Powerline Road faults; Dibblee mapped a fault similar to the Powerline Road fault (figures 2a, 2b).

The Juniper Ranch fault is located entirely within basement rocks (Meisling, 1984). The magnitude and sense of displacement are uncertain, but Meisling speculated that it is probably vertical, down to the west. Meisling stated that the fault is not well-defined and assumed the fault to be inactive.

The Powerline Road fault is a high-angle fault with down-to-the-west vertical displacement. The magnitude of displacement is not known. The Powerline Road fault doesn't offset the upper part of Meisling's Qf2 alluvial unit (~ 100,000 ybp) and, according to Meisling, is not geomorphically well-defined. Meisling considered the Powerline fault to be inactive.

ARRASTRE CANYON GRABEN

The Arrastre Canyon graben is a complex, northeast-trending zone of faults consisting of the Bowen Ranch, Arrastre Canyon Narrows, and Lovelace Canyon faults (figures 2a, 2b). Displacement along this fault zone was right-lateral strike-slip during its early evolution, followed by dip-slip displacement, and is currently reverse in response to compression (Meisling, 1984).

Bowen Ranch Fault

The Bowen Ranch fault is a north-northeast-trending fault that forms the western side of the Arrastre Canyon graben (figure 2a). The fault has been mapped by both Dibblee (1974) and Meisling (1984), although only Meisling's fault is shown on figure 2a. The sense of displacement along the Bowen Ranch fault is right-lateral oblique according to Meisling. About 1/2 km of right-lateral separation of Cretaceous bedrock was reported, as well as about 30 meters of vertical displacement of mid-Pleistocene terrace deposits (east side down) (Meisling, 1984). Holocene terrace deposits are not offset along the fault (locality 9, figure 2a). Meisling reported that the fault is delineated by geomorphic features such as linear drainages, aligned saddles and notches, and "disturbed" drainage patterns. Some drainages are deflected left-laterally, which conflicts with the bedrock evidence indicating right-lateral offset. Meisling concluded that this conflicting evidence suggests a small amount of late Pleistocene vertical offset.

Arrastre Canyon Narrows Fault

The Arrastre Canyon Narrows fault is a northeast to east-northeast-trending, generally high-angle fault zone mapped by Dibblee (1974) (not plotted) and Meisling (1984) (figures 2a, 2b). The fault consists of several segments and is complex. The style and magnitude of displacement are not well understood. Meisling (1984) mapped the central segment as right-lateral and reported a compressional ridge in bedrock. In addition, Meisling reported about 1/4 km of right-lateral displacement of a structural feature in Cretaceous bedrock. Middle Pleistocene Ord River Gravel is offset vertically

(northwest side down) at locality 10 (figure 2a). Holocene alluvium is juxtaposed against Ord River Gravel deposit near locality 10 (figure 2a).

The geomorphic expression of the Arrastre Canyon Narrows fault is not well-defined according to Meisling. He was not certain whether the saddles, benches, and troughs in bedrock were the result of differential erosion or recent faulting. Furthermore, the geomorphic expression of the fault zone is variable according to Meisling, indicating a lack of recent, systematic faulting.

The Arrastre Canyon Narrows fault complexly joins with the Sky High Ranch fault to the east (figure 2a). Because the Sky High Ranch fault is considered to be potentially active by Meisling, he also considered the Arrastre Canyon Narrows fault to be potentially active due to its connection with the Sky High Ranch fault. A trench was excavated across a segment of the Arrastre Canyon Narrows fault at locality 11 (figure 2a). The trench was excavated in Holocene alluvium of Lovelace Canyon and no evidence of recent faulting was reported. However, the alluvium at this location is probably late Holocene in age, so a lack of Holocene activity cannot be demonstrated at this site.

Lovelace Canyon Fault

The Lovelace Canyon fault is a northeast-trending, probably high-angle strike-slip fault (figure 2a). Meisling (1984) and Dibblee (1974) mapped segments of the Lovelace Canyon fault (Dibblee's fault not plotted). Approximately 1 km of right-lateral strike-slip displacement has occurred along the Lovelace Canyon fault, based on the truncation of the axis of a dome in bedrock (Meisling, 1984). Meisling found no compelling evidence for recent activity along the Lovelace Canyon fault. He reported that the fault is not characterized by geomorphic evidence of recent faulting, and interpreted the fault to be pre-middle Pleistocene in age.

TUNNEL RIDGE LINEAMENT

The Tunnel Ridge lineament is a significant northeast-trending fault in bedrock mapped by Dibblee (1974) and Meisling (1984) (Dibblee not plotted) (figure 2b). The style and magnitude of offset of the Tunnel Ridge lineament is not known. Meisling pointed out that significant vertical displacement along the Tunnel Ridge lineament has not occurred because of the relative continuity of the late Miocene erosion surface across the fault. Left-lateral strike-slip displacement probably characterizes the fault at its southern end where it complexly joins the Cleghorn fault, a Holocene-active, left-lateral strike-slip fault (Meisling, 1984). Geomorphic expression of the Tunnel Ridge lineament is limited mainly to broad, linear valleys developed on the late Miocene erosion surface (Meisling, 1984). Although Meisling did not evaluate the Tunnel Ridge lineament in detail, he assumed that the fault must have had displacement since middle Pleistocene time, based mainly on the fault's association with the Cleghorn fault to the southwest and the Sky High Ranch fault (via the Arrastre Canyon graben) to the northeast.

POWERLINE CANYON FAULT

The Powerline Canyon fault is a west-northwest-trending, near-vertical fault mapped by Meisling (figure 2b). The style and magnitude of the fault are not known. The Powerline Canyon fault is overlain by and does not offset

terrace deposits of unknown age (locality 12, figure 2b). Meisling assumed that the age of this terrace deposit may pre-date uplift of the Ord Mountains (late Pliocene to early Pleistocene). The Powerline Canyon fault is not characterized by geomorphic evidence of late Quaternary activity (Meisling, 1984, p. 317), and was considered to be inactive by Meisling.

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Aerial photographic interpretation by this writer of faults in the northwest San Bernardino Mountain study area was accomplished by using U.S. Department of Agriculture (AXL, 1953, scale 1:20,000), U.S. Bureau of Land Management (CAHD-77, 1978, scale 1:30,000), U.S. Geological Survey (1975, scale 1:13,000; GS-VCGN, 1969, scale 1:30,000), and U.S. Army Corps of Engineers (MR, 1939, scale 1:20,000) air photos.

Approximately four days were spent in the study area in early September 1986 by this writer. Selected fault segments were verified and subtle features not observable on the aerial photographs were mapped in the field. Results of aerial photographic interpretation and field observations by this writer are summarized on figure 3.

NORTH FRONTAL FAULT ZONE

The NFFZ in the study area is characterized by a complex zone of both low-angle reverse faults, high-angle strike-slip faults, and associated folds. Mapping by this writer generally verified late Pleistocene faults mapped by Meisling (1984), and, locally, faults mapped by Miller (1975-77), and Dibblee (1974) (figures 2a, 2b, 3).

White Mountain Thrust System

The segment of the White Mountain Thrust System northeast of the Sky High Ranch fault is generally well-defined and is delineated by a well-defined scarp in late Pleistocene alluvial fans, ponded alluvium, and tonal lineaments in Holocene alluvium (figure 3). A Holocene terrace deposit overlies and is not offset along the fault (locality 13, figure 3). At locality 14, the scarp is about 36 meters high and has a scarp-slope angle of 34°. The age of the alluvial fan is thought by Meisling (1984) to be about 400,000 years old. Preliminary studies of soil development on comparable alluvial fan surfaces east of the study area suggest the age of the fan surface to be about 130,000 years old (Bryant, 1986; Borchardt, 1986).

The segment of the White Mountain Thrust System mapped by Meisling northeast of the Sky High Ranch fault was verified by this writer (figures 2a, 3). This segment of the fault is more continuous than mapped by Miller (1975-1977). West of the Sky High Ranch fault, segments of the White Mountain Thrust System are not delineated by geomorphic evidence of recent faulting and are not well-defined.

Sky High Ranch Fault

The Sky High Ranch fault in the study area is generally well-defined and is delineated by geomorphic features indicating latest Pleistocene to Holocene strike-slip displacement, such as scarps in alluvium, shutter ridges, a sidehill bench, ponded Holocene alluvium, and a right-laterally offset geomorphic surface (e.g., localities 15, and 16, figure 3). Northwest of

locality 16, the fault splays into several, less well-defined segments generally delineated by subdued, northeast-facing scarps in late Pleistocene alluvium (figure 3). The faulting northwest of locality 16 is more characteristic of a south-dipping reverse fault. It was not possible during this study to ascertain whether the subdued, generally poorly defined scarp in late Pleistocene alluvium delineates a fault or fold in near-surface materials.

Drainage deflections along the Sky High Ranch fault southeast of locality 16 do not reflect systematic right-lateral strike-slip displacement. The majority of drainages are left-laterally deflected and are probably the result of stream capture rather than left-lateral displacement. The right-laterally offset geomorphic surface at locality 16 (figure 3) indicates right-lateral offset along the Sky High Ranch fault.

Ocotillo Ridge "Fold"

The Ocotillo Ridge "fold" is delineated by a moderately defined and degraded north-facing scarp in mid-Pleistocene Ord River Gravel deposits (figure 3). Additional geomorphic features associated with this structure include faceted spurs and a subtle tonal lineament in Holocene alluvium (e.g., locality 17, figure 3). The faceted spurs along the north-facing scarp are probably resistant gravel beds.

This writer visited Meisling's trench site at locality 4 (figures 2a, 3). Steeply north-dipping beds of Ord River Gravel deposits were verified by this writer. Within about 120 meters, bedding in the Ord River Gravel deposits changes from a gentle northerly dip ($\sim 30^\circ$) to a 21°N dip about 15 meters from the south end of the trench, to 55°N in the trench. Based on the intensity of deformation of the gravel deposits and the relatively short trench excavated by Meisling (~ 20 meters), it is possible that a fault may exist just north of the trench site, probably concealed by the debris slope derived from the scarp. The location of the fault may be 15 to 30 meters north of Meisling's trench, based on air photo interpretation by this writer (locality 4, figure 3). Thus, the presence of a fault along the base of Ocotillo Ridge has not conclusively been demonstrated.

Ord Mountains Fault Zone

Apple Valley Highlands Fault

The generally north-trending Apple Valley Highlands fault is delineated by a well-defined, west- to northwest-facing scarp in late Pleistocene alluvium (figure 3). Faults mapped by Miller (1975-77) and Meisling (1984) generally were verified by this writer. Geomorphic features indicating latest Pleistocene, and possibly Holocene reverse faulting associated with this scarp include "wine-glass" shaped drainages, vertically offset drainages, faceted spurs, a possible graben on the upthrown block, and tonal lineaments in Holocene alluvium (e.g., localities 18-20, figure 3).

The west-facing scarp is dissected and alluvial fans issuing from the scarp are not offset. The unmodified constructional surface (bar and swale topography), lack of boulder weathering, and lack of desert pavement suggest that these fans are late Holocene in age. Scarp heights in late Pleistocene alluvium vary from 70 meters (reported by Meisling, 1984) near locality 6 (figure 2a) to 15 meters at locality 19 (figure 3). Scarp-slope angles are about 27° to 28° , and crests are somewhat rounded (figure 3). The offset late Pleistocene alluvium (Meisling's Qf2) has a well-developed stage IV

K horizon and an overlying B horizon. Meisling's observation that the K horizon was downwarped at the fault was partly verified by this writer along a branch fault (locality 22, figure 3).

Deep Creek Fault

The Deep Creek fault is delineated by a moderately to poorly defined scarp in late Pleistocene alluvium (figure 3). The west-facing scarp mapped by Miller (1975-77) and Meisling (1984) was generally verified as to location by this writer. However, the Deep Creek fault lacks the youthful geomorphic features of the AVHF, the scarp is much more degraded, and much of the fault is concealed by Holocene alluvium.

Juniper Ranch and Powerline Road Faults

These north-northeast-trending faults are not well-defined and are not characterized by geomorphic features indicating recent faulting (figures 2a, 2b).

ARRASTRE CANYON GRABEN

Bowen Ranch Fault

The Bowen Ranch fault is a moderately well-defined strike-slip fault (figure 2a). Geomorphic features in granitic bedrock, such as aligned saddles, linear ridges and drainages, and left-laterally deflected drainages are characteristic of late Quaternary displacement, but evidence of latest Pleistocene to Holocene displacement is permissive to weak (figure 2a). Geomorphic evidence of right-lateral strike-slip displacement was not verified by this writer and, except for a vertically offset drainage that is probably not fault related (locality 23, figure 2), there is no well-defined geomorphic evidence of recent vertical displacement.

Arrastre Canyon Narrows Fault

The Arrastre Canyon Narrows fault is a complex, generally poorly defined fault zone in bedrock (figures 2a, 2b, 3). Geomorphic features delineating the fault, such as linear drainage, saddles, deflected drainages, and linear ridges, are not characteristic of recent faulting and are not supportive of systematic strike-slip displacement. The fault segment near locality 10 (figure 2a) that offsets mid-Pleistocene Ord River Gravels (Meisling, 1984) is not well-defined and is not delineated by geomorphic features characteristic of recent faulting. An exposure of a segment of the Arrastre Canyon Narrows fault at locality 24 (figure 2a) indicates that this segment of the fault is strike-slip. The fault plane in granitic bedrock is vertical to near-vertical and horizontal striations were observed along individual fault planes. No evidence of recent faulting was observed at this site.

Lovelace Canyon Fault

The Lovelace Canyon fault is a moderately to poorly defined, northeast-trending fault in bedrock (figure 2a). The fault is delineated principally by a broad linear drainage in bedrock; geomorphic evidence of recent faulting was not observed by this writer, based on air photo interpretation.

TUNNEL RIDGE LINEAMENT

The Tunnel Ridge lineament is a moderately defined, northeast-trending fault in bedrock (figure 2b). The fault is delineated by geomorphic features such as linear and deflected drainages and aligned saddles in bedrock (figure 2b). Geomorphic evidence of recent, systematic strike-slip displacement was not observed by this writer along the Tunnel Ridge lineament, based on brief air photo interpretation. The junction at Miller Canyon between the Cleghorn fault and the Tunnel Ridge lineament was not evaluated in this FER, but will be evaluated with the Cleghorn fault (FER-187).

POWERLINE CANYON FAULT

The Powerline Canyon fault is a moderately well-defined, west-northwest-trending fault in bedrock (figure 2b). The fault is delineated by geomorphic features that are more characteristic of differential erosion along a fault, such as a broad trough, linear drainages, left-laterally deflected drainages, and a north-facing bedrock escarpment (figure 2b).

SEISMICITY

Seismicity in the northwestern San Bernardino Mountains study area is depicted in figure 5. A and B quality epicenter locations by California Institute of Technology are for the period 1932 to 1985.

Segments of the NFFZ in the study area are seismically active. Clusters of epicenters in proximity to the Sky High Ranch fault indicate that it is seismically active, although the fault is not associated with a well-defined zone of microseismicity. The Ord Mountains fault zone generally has a low rate of seismicity except for a cluster of epicenters near the stepover between the AVHF and the Deep Creek fault.

A small cluster of epicenters is located near the junction between the Arrastre Canyon Graben and the Tunnel Ridge lineament. Additional epicenters occur in the study area, but are not associated with any surface faults.

CONCLUSIONS

NORTH FRONTAL FAULT ZONE

The NFFZ is a major, east-, north-, and northwest-trending fault zone that marks the boundary between the Transverse Ranges and Mojave Desert geomorphic provinces. The NFFZ in the study area consists of the White Mountain Thrust System, Ord Mountains fault zone, Sky High Ranch fault, and related faults (figures 2a, 2b, 3).

White Mountain Thrust System

The White Mountain Thrust System is not well-defined and does not have geomorphic evidence of recent faulting, except for a segment of the fault located northeast of the Sky High Ranch fault (figures 2a, 3). This segment is well-defined and is delineated by a scarp in late Pleistocene alluvial fans (localities 13, 14, figures 2a, 3). Associated geomorphic features, such as

ponded alluvium, relatively steep scarp-slope angles (27° - 34°), and tonal lineaments in Holocene alluvium, indicate latest Pleistocene reverse faulting and are suggestive of Holocene displacement. Mapping by Meisling (1984) along this segment of the fault was verified by this writer (figures 2a, 3).

Sky High Ranch Fault

The Sky High Ranch fault is a generally well-defined northwest-trending, right-lateral strike-slip fault (figures 2a, 3). The fault is characterized by geomorphic evidence of latest Pleistocene and possible Holocene strike-slip displacement (figure 3). Meisling (1984) reported that approximately 1/2 km of right-lateral offset has occurred along the Sky High Ranch fault since deposition of late Pleistocene alluvial fans. These fans are thought by Meisling (1984) to be approximately 400,000 years old, but preliminary soils studies by Borchardt (1986) suggest that equivalent alluvial fans east of the study area may be about 130,000 years old. Northwest of locality 16 (figures 2a, 3), the Sky High Ranch fault splays into several branches and generally is not as well-defined (figures 2a, 3). The northernmost branch offsets late Pleistocene alluvium in a down-to-the-north reverse (?) sense of displacement, but the scarp is generally poorly defined (figure 3).

Ocotillo Ridge "Fold"

The Ocotillo Ridge "fold" was mapped by Dibblee (1974) as an anticline, by Miller (1975-77) as a faulted anticline, and by Meisling (1984) as a monoclinical warp in middle-Pleistocene alluvium (figure 2a). This structure is delineated by a moderately defined, degraded, north-facing scarp in middle-Pleistocene alluvium. On the west, the structure changes to a southerly trend and joins with the Apple Valley Highlands fault. Meisling (1984) concluded that this scarp delineated a fold at the surface that was formed in response to faulting at depth. This conclusion was based on a 20-meter-long trench at locality 4 (figures 2a, 3, 4), where no faulting was reported. Although the trench was not long enough to conclusively demonstrate that fault planes are not located farther to the north, the north-facing scarp is degraded and is not characterized by geomorphic features indicative of Holocene faulting.

Ord Mountains Fault Zone

Apple Valley Highlands Fault

The Apple Valley Highlands fault is a well-defined, north-trending reverse fault that offsets late Pleistocene alluvium (figures 2a, 2b, 3). Mapping by Miller (1975-77) and Meisling (1984) generally was verified by this writer (figures 2a, 2b, 3). Geomorphic evidence of latest Pleistocene and, possibly, Holocene faulting includes a well-defined scarp in late Pleistocene alluvium, "wine-glass" shaped drainages and vertically offset drainages, and tonal lineaments in Holocene alluvium (figure 3). Scarp-slope angles measured along segments of the Apple Valley Highlands fault are 27° to 28° , possibly indicating the youthfulness of the scarp (figure 3). Although the offset alluvium is well indurated due to extensive K horizon development (stage IV), the K horizon and overlying B soil horizon are warped down at the fault (Meisling, 1984, p. 187), indicating that faulting is much younger than the age of the late Pleistocene alluvium.

Deep Creek Fault

The Deep Creek fault is a poorly defined north to east-northeast-trending reverse fault mapped by Miller (1975-77), Meisling (1984), and Dibblee (1974) (figure 2b). Although the location of the fault was generally verified by this writer, geomorphic evidence of recent faulting was not observed (figure 2b).

Juniper Ranch and Powerline Road Faults

These high-angle faults associated with the Ord Mountains fault zone are not well-defined and do not have geomorphic evidence of recent faulting (figures 2a, 2b). Meisling (1984) concluded that these faults did not have evidence of late Quaternary displacement.

ARRASTRE CANYON GRABEN

Bowen Ranch Fault

The Bowen Ranch fault mapped by Meisling (1984) is a moderately well-defined, north-northeast-trending fault in bedrock (figure 2a). Middle-Pleistocene alluvium is offset along the fault (locality 10, figure 2a). Geomorphic features in bedrock delineating the fault, such as aligned saddles and notches, linear drainages and ridges, and troughs suggest recent faulting, but could also be the result of differential erosion along the fault (figure 2a). Systematic offset of drainages was not observed along the fault. There is no compelling evidence for recency along the Bowen Ranch fault, although an active fault with a very low slip-rate cannot be ruled out.

Arrastre Canyon Narrows Fault

The Arrastre Canyon Narrows fault is a multiple strand, east-northeast-trending fault mapped by Meisling (1984) (figure 2a). The fault zone generally is poorly defined and geomorphic evidence of recent faulting was not observed by this writer, based on air photo interpretation and limited field checking. Meisling classified the fault zone as potentially active, based on the association with the Sky High Ranch fault. Meisling did not report additional evidence of recent faulting.

Lovelace Canyon Fault

The Lovelace Canyon fault is a moderately to poorly defined, northeast-trending fault in bedrock mapped by Meisling (1984) (figure 2a). Geomorphic evidence of recent faulting was not observed by this writer, based on air photo interpretation. Meisling (1984) concluded that the fault has not been active since middle-Pleistocene time.

TUNNEL RIDGE LINEAMENT

The Tunnel Ridge lineament is a moderately defined, northeast-trending fault in bedrock mapped by Dibblee (1974) and Meisling (1984) (figure 2b). Meisling stated that the sense of displacement is not known along this fault, but he ruled out significant vertical offset because the late Miocene erosion surface is relatively continuous across the fault. Geomorphic evidence of

photo interpretation (figure 2b). However, the junction between the active Cleghorn fault and the southern Tunnel Ridge lineament in Miller Canyon was not evaluated in this study, but will be evaluated in FER-187.

POWERLINE CANYON FAULT

The Powerline Canyon fault is a west-northwest-trending fault in bedrock mapped by Meisling (1984) (figure 2b). Meisling reported that a terrace deposit that overlies and is not offset by the fault may pre-date uplift of the Ord Mountains, indicating that the Powerline Canyon fault is pre-late-Quaternary. The fault is moderately well-defined in bedrock, but geomorphic features delineating the fault are probably the result of differential erosion along the fault (figure 2b).

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1985).

NORTH FRONTAL FAULT ZONE

Zone for special studies well-defined segments of the White Mountain Thrust System, Sky High Ranch fault, and Apple Valley Highlands fault shown on figure 6. Do not zone segments of the Deep Creek, Juniper Ranch, and Powerline Road faults. Principal references cited should be Miller (1975-77), Meisling (1984), and this FER. Do not zone the Ocotillo Ridge "fold". This structure is generally not well-defined and may not be a surface fault.

ARRASTRE CANYON GRABEN

Do not zone segments of the Bowen Ranch, Arrastre Canyon Narrows, and Lovelace Canyon faults. Those faults are neither sufficiently active nor well-defined.

TUNNEL RIDGE LINEAMENT

Do not zone for special studies. This fault is neither sufficiently active nor well-defined. Recommendations for the southern Tunnel Ridge lineament near Miller Canyon will be made in FER-187 (Cleghorn fault).

POWERLINE CANYON FAULT

Do not zone for special studies. This fault is not sufficiently active.

*I have reviewed;
agree with the
recommendations.
Earl W. Hart
12/23/86*

William A. Bryant
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December 8, 1986

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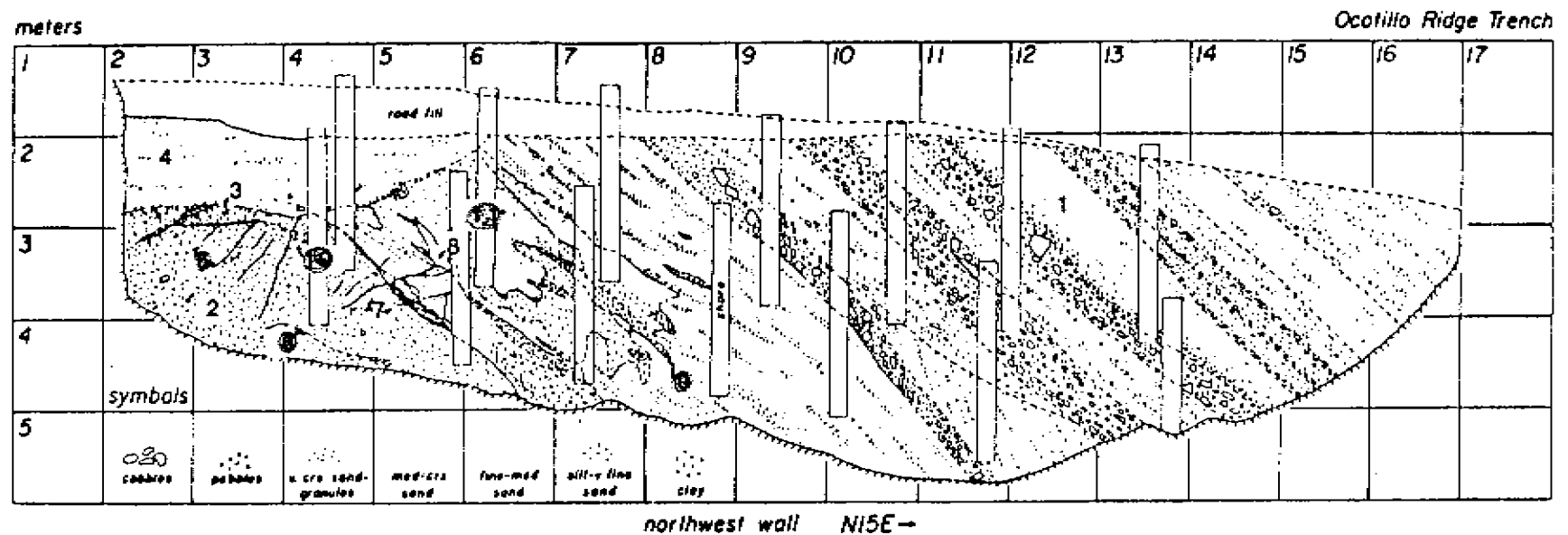
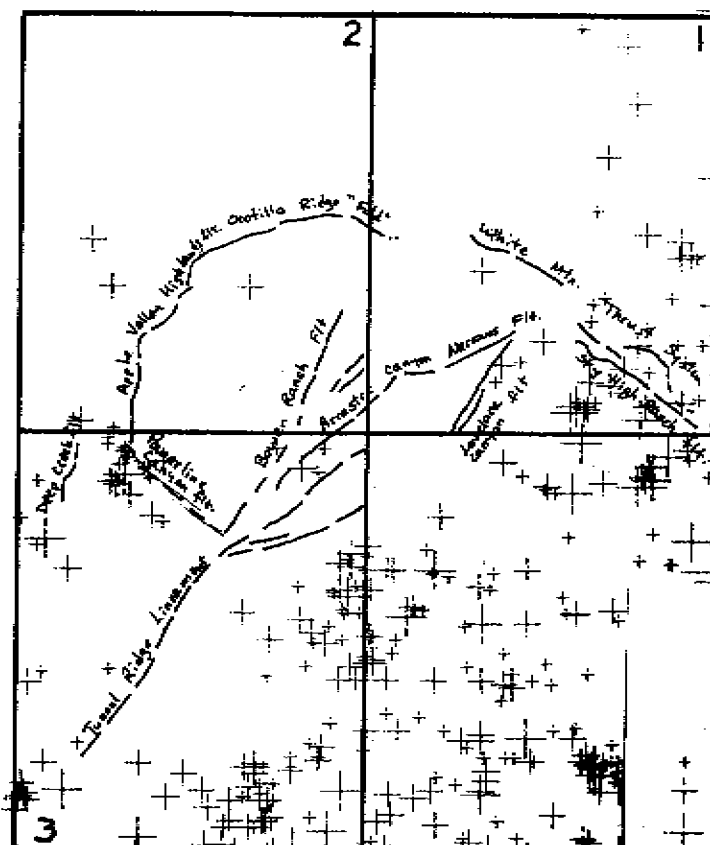


Figure 4 to (FER-186). Log of Ocotillo Ridge trench excavated by Meisling (1984) (refer to locality 4, figures 2a and 3 for location of trench). CaCO_3 -cemented fractures (#5 and 6 on log) and liquefaction features (#9-11) were reported in mid-Pleistocene Ord River Gravel deposits. Meisling reported no evidence of faulting in this north-dipping homocline.

Index to 7½' qds

1. Fifteensmile Valley
2. Apple Valley South
3. Lake Arrowhead



MAGNITUDE

..... 1.0 TC 1.9
 2.0 TC 2.9
 3.0 TC 3.9
 4.0 TC 4.9
 5.0 TC 5.9

Figure 5 (to FER-186). Seismicity (A and B quality) in the northwestern San Bernardino Mountains study area for the period 1932 to mid-1985, based on locations from California Institute of Technology (1985). Faults are from Rogers (1967) and Bortugno and Spittler (1986), scale 1:250,000.